Current-driven Emission of Spin Waves from Magnetic Vortices

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Flash memories and processing units today rely on exploiting electronic charges, where CMOS technologies have improved massively over the past decades. Nevertheless, high-power consumption, and frequency limitations, lead to the search of alternative concepts in the field of spintronics[1]. In that respect, magnons, the quanta of spin-waves, are a potential candidate for all-magnon based devices ranging from multiplexers to half-adders, and subsequently enabling proof-of-principle magnon-based-computing[2]. Coherent spin-waves are usually excited by means of microwave antennas, where locally focused alternating external Zeeman fields perturb the magnetization. Often the lack of antennas with high excitation efficiency limits the experimental achievable structures that can be investigated. Recently, it was shown that magnetic discs with stable vortex states can be used to excite and propagate spin-waves, when subjected to alternating uniform magnetic fields[3]. Relatively high spin-wave amplitudes with sub-µm wavelengths were observed for a stacked pair of vortices coupled antiferromagnetically (AF) to each other.

In this contribution, we report a micromagnetic study, where AF-coupled vortices in synthetic antiferromagnetic (SAF) stack consisting of two disks of $4\,\mu\mathrm{m}$ diameter, and thickness of $45\,\mathrm{nm}$ are subject to in-plane alternating currents. As central finding, we observe current-driven spin-wave emission from the cores of these vortices. Depending on the particular chirality of the system, there are fundamental differences in the spin-wave propagation direction. Furthermore, we demonstrate that the effect that leads to the spin-wave excitation and propagation is the Oersted field generated by the electric current flowing directly through the SAF stack. We compare this Oersted effect to that predicted for spin-transfer-torques (STT) acting on the vortex core. We find that in the latter STT case in the given geometry, 100 times higher currents are required to noticeably excite spin waves, yet still with one order of magnitude lower amplitude than in the Oersted driven case (see Figure 1). We further compare the excitation efficiency of spin waves generated by current-driven Oersted field (CDOF) to that from the magnetic field of a stripline antenna. We observe that also here the spin-waves emission is more coherent, and one order of magnitude more efficient when the spin-waves are excited via CDOF. Our findings are supported by time-resolved scanning transmission X-ray microscopy (TR-STXM) experiments, where the magnetic ortices are directly observed to efficiently emit spin waves upon CDOF excitation.

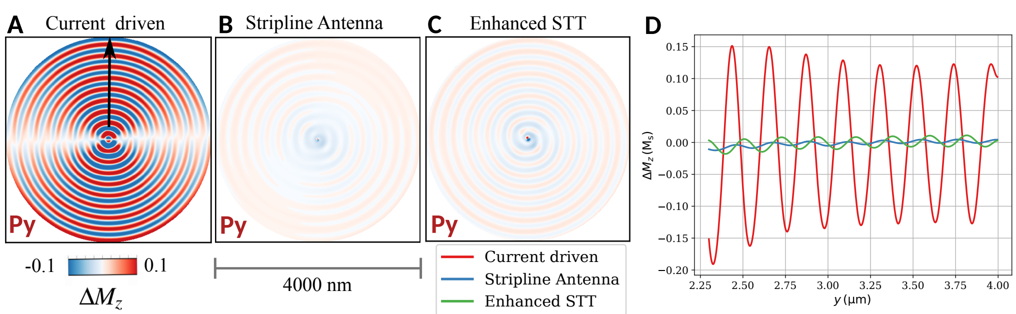

Figure 1: Spin wave amplitude profiles given by ΔM_z after excitation with (A) Current-driven Oersted field (CDOF), (B) Uniform field of equal amplitude $H_y^{\mathrm{CDOF}} = H_y^{\mathrm{Stripline}} = 400\,\mathrm{Am}^{-1}$ if the magnetic field would have been generated by a strip line antenna, and the STT excitation with the amplitude of the current being increased two orders of magnitude. The spin-wave amplitude along y depicted in (A) is plotted in (D).

References

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